Research Report
KTC-89-11

EARTHQUAKE HAZARD MITIGATION OF TRANSPORTATION FACILITIES FOR HENDERSON COUNTY

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16. Abstract
Concern has grown in recent years over the seismic activity of the New Madrid seismic zone in Western Kentucky. Henderson County, Kentucky is located in this region. To permit emergency medical, supply, and equipment traffic into this area after an earthquake has occurred, the Kentucky Transportation Cabinet is interested in the possibility of keeping selected routes passable. This report lists the routes that have been investigated and recommended as being the routes in Henderson County that should be maintained in a passable condition. The recommended routes, US 60, US 41, KY 351, KY 416 and Audubon Parkway have been visually surveyed and all seismically significant features cataloged. These features are logged by their location on strip maps contained in Appendix A and a detailed listing of all the potentially critical features is given in Appendix B.

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INTRODUCTION

An awareness of earthquakes and their possible effects upon the nation's infrastructure is critically important to the public, and in particular, to public officials. The nation's highway system is one of the most important components of the infrastructure. After the occurrence of an earthquake, the highway system is the primary mode of transporting emergency supplies and services into an affected area. Thus, it is important to catalog the important components of the highway system and attempt to anticipate the possible damage to these components from an earthquake.

Western Kentucky in general and Henderson County in particular are in a high risk earthquake zone. In 1811-1812, three of the most severe earthquakes in American history shook the country. The location of these quakes was not on the infamous San Andreas fault nor anywhere along the well-known fault laden Pacific coast but was near a small town on the Mississippi River where the states of Kentucky and Missouri share a border (Figure 1). It is this river town, New Madrid, Missouri, that is the namesake of a region now regarded by seismologists and disaster response planners as the most hazardous earthquake zone east of the Rocky Mountains -- the New Madrid seismic zone.

In addition to these three great earthquakes, there are several other well documented factors demonstrating the susceptibility of the New Madrid region to the recurrence of major earthquakes. Through a decade of extensive research, an ancient crustal rift has been found to underlie the relatively shallow sediments comprising the region's surface. This type of geologic structure is prone to seismic activity. The New Madrid rift has been identified as being of sufficient size to generate major earthquakes. Further evidence of the area's seismicity is the record of over 2,000 earthquakes detected in the zone since 1974. Though most have been of a magnitude below the threshold of human perception, their existence clearly indicates the high level of seismic activity occurring in the zone.

Seismologists have calculated the probabilities of recurrence of sizeable earthquakes in the New Madrid rift zone. The probability of a magnitude 6.3 earthquake (Richter scale) within 50 years is from 86 to 97 percent. The probability (1) of that same earthquake occurring within the next 15 years is from 40 to 63 percent. For comparison, the 1971 San Fernando earthquake (magnitude 6.6) killed 58 people and caused $480 million worth of damage. The 1988 Armenian earthquake of similar magnitude killed approximately 25,000 to 30,000 people.

The probability of a magnitude 7.6 earthquake occurring within 50 years is from 19 to 29 percent. The probability for this size earthquake occurring within 15 years drops to a range of 5.4 to 8.7 percent. On February 4, 1975, the Haicheng earthquake in China had a magnitude of 7.3 and destroyed or damaged about 90 percent of the structures in a city of 90,000 people.

When comparing historical earthquakes of similar magnitude, one must take into consideration

that death totals and damage estimates will vary greatly due to the geology, population density, types of building, and quality of construction.

For a given earthquake, effects at a given location are described by the Modified Mercalli Intensity (MMI) scale (2) which ranges from I (no damage and felt only by instruments) to XII (total destruction). Details of the MMI scale are given in Table 1. Values of MMI associated with the 1811-1812 earthquakes are shown in Figure 1. The potential for damage and destruction from earthquakes in the region is significant.

In 1982, the Governor's Task Force on Earthquake Hazards and Safety was created to evaluate Kentucky's earthquake risk and to make recommendations for responding to those risks. This task force recommended increased public awareness and education programs, improved emergency response planning and training, improved building codes and seismic restraint designs, evaluation of other mitigation measures, and participation in national and regional earthquake forums and funding programs.

In 1984, Governor Collins created the Governor's Earthquake Hazards and Safety Technical Advisory Panel (GEHSTAP) to analyze scientific and engineering data regarding seismic risks in Kentucky and to make specific recommendations on mitigation, public awareness, response planning, and policy development for public health and safety. The States are dependent on their highway systems for the movement of goods and services. Due to the possible adverse effects a major earthquake could have on this system, the Earthquake Stability and Transportation Subcommittee (ESTS) of GEHSTAP was formed.

ESTS has encouraged the Kentucky Transportation Cabinet to secure funding for generating and implementing an earthquake hazard mitigation plan in an attempt to safeguard the highway system against catastrophic earthquake failure. As a result, the Cabinet commissioned the Kentucky Transportation Center at the University of Kentucky to analyze and assess the possible effects of an earthquake on highway facilities. The study area includes the 26 western-most counties in Kentucky that are adjacent to the New Madrid seismic zone (Figure 1). To date, one of the results of that study has been the recommendation that over 1,000 miles of highways in the study area be utilized as emergency or "priority" routes. These would be the primary routes used for transporting emergency supplies and personnel after an earthquake. Also, it is anticipated that these would be the first routes repaired after an earthquake.

The initial task in identifying these priority routes was to decide where they should begin; that is, in the event of a major earthquake, the point at which the transport of goods and services would originate. Ideally, the city chosen should possess the following attributes:

1. Sufficient size to contain all necessary personnel, supplies, and facilities to respond quickly to a major emergency;

2. Proximity to the high hazard

area to speed the relief effort but not so close as to suffer the same high risk potential;

3. Easy access from other major cities in the State; and

4. Sufficient routes to provide relatively direct access to all 26 high-risk counties.

The city best fitting these criteria is Bowling Green. Located at the eastern edge of the earthquake zone in Warren County, Bowling Green meets both the size criterion (population 40,450) and the accessibility criterion (Louisville and Nashville via I 65 and Lexington via the Bluegrass Parkway). Bowling Green provides access to the 26-county area via US 68/KY 80; this road was chosen as the main east-west artery because it crosses Lake Barkley and Kentucky Lake upstream from the dams impounding those bodies of water.

As a first step towards establishing an overall policy for earthquake hazard mitigation in the highway system, these priority routes have been visually surveyed and all natural and man-made features along these routes that are considered seismically significant were cataloged. With this information, a realistic and cost-effective plan for "hardening" these routes against earthquakes can be established. Such efforts are currently under way.

PRIORITY ROUTE IN HENDERSON COUNTY

Henderson County is located approximately 120 miles northeast of the center of the New Madrid Seismic Zone. Figure 1 indicates that Henderson County is located in the X, IX, and the VIII bands of the MMI scale. Approximately 85 percent of Henderson County is located within the IX band. This indicates considerable damage could occur in Henderson County in the event of a major earthquake.

US 60, US 41, KY 351, KY 416 and the Audubon Parkway have been designated as the priority routes for Henderson County. US 60 starts at the Henderson County-Union County line and continues north for 11.0 miles, ending in the City of Henderson. US 41 starts at the Henderson County-Webster County line and continues north for 13 miles, ending at the junction of KY 812 (heading south) and US 60. KY 351 starts at the junction of KY 351 and US 41, ending 11.5 miles east. KY 416 starts at the junction of KY 416 and KY 51, ending 2.32 miles west. The Audubon Parkway starts at the Henderson County-Daviess County line and continues west 5.7 miles, ending at the junction of KY 416.

A number of features along the priority routes could potentially hamper rescue and relief efforts. These features included bridges, soil fills, cut slopes, gas pipelines, power lines, large trees, underground mines, water impoundments, oil tanks, radio/TV towers, and water towers. These features are logged by their location on strip maps contained in Appendix A and a detailed listing of all potentially critical features is given in Appendix B.

BRIDGES

Bridges are the most significant and important features on the priority

route. With few exceptions, existing highway bridges in the study area have not been designed to resist motions and forces that may be generated by earthquakes. Bridges located within the seismic zone could possibly be damaged, thus reducing their load-carrying ability. In some cases, damage could be sufficiently great to cause complete collapse. Several types of damage could occur:

1. A bridge could fail at the bearing which supports the main spans, causing the spans to fall from the bearings and possibly from the piers or abutments.

2. Failure could occur in the columns, piers, or footings which would reduce the load-carrying capacity of the bridge, if the bridge was still in place.

3. An abutment could tilt allowing the entire span to fall.

4. Soil movement or slumping could affect the bridge approach fills, damaging the abutments or piers, or making the bridge inaccessible.

There are five bridges on US 60, five bridges on US 41, two on KY 351, one on KY 416, and one on the Audubon Parkway in Henderson County. The bridges are located over:

US 60

1. Highland Creek,

2. Race Creek,

3. Canoe Creek,

4. US 41 Bypass,

5. US 41A.

US 41

1. King Creek,

2. East Fork of Cane Creek,

3. Dredged Ditch,

4. Elam Ditch,

5. Branch of Canoe Creek.

KY 351

1. Pennyrile Parkway crosses over KY 351,

2. Lick Creek.

KY 416

1. Audubon Parkway.

Audubon Parkway

1. Green River

Research is currently under way studying the effects that an earthquake could have on these bridges and their approach fills.

FILLS

Highway fills are particularly important because of their tendency to fail from seismically induced motions. Fills fail in one of two major modes. The first is a generalized circular or wedge-shaped failure resulting in one or both traffic lanes moving down and out. If both lanes failed, this would certainly render the route impassable and immediate repairs would be necessary. The second mode of failure is a general slumping or settling of the

embankment. The roadway would probably remain passable if settlement or slumping were not severe but reduced speed limits would be required for safety.

Large fills on priority routes in Henderson County are located as follows:

US 60

1. Approach fills for the bridges over Highland Creek and Race Creek,
2. 2.0 miles north of junction KY 266 and US 60,
3. 0.45 mile south of junction US 41A, KY 425 and KY 136,
4. Approach fills for the bridge over Canoe Creek,
5. Approach fills for the bridges over US 41 Bypass and US 41A.

US 41

1. Approach fills for the bridge over King Creek,
2. Approach fills for the bridge over the East Fork of Cane Creek,
3. Approach fills for the bridge over Dredged Ditch,
4. Approach fills for the bridge over Elam Ditch,
5. Approach fills for the bridge over a Branch of Canoe Creek.

KY 351

1. Approach fills for the bridge over Lick Creek.

KY 416

1. Approach fills for the bridge over Audubon Parkway,
2. 0.12 mile north of the bridge over Audubon Parkway.

Audubon Parkway

1. Approach fills for the bridge over Green River,
2. 0.10, 2.90, 3.50, 4.40 and 5.00 miles west of the Henderson County-Daviess County line.

GAS PIPELINES

Three gas pipelines cross under US 60, two under US 41, and one under KY 351. It is possible that pipelines could fail under or near a priority route causing a temporary closure. If a pipeline failed, an explosion might destroy a section of the priority route. Repair could be delayed by further gas leaks, fire, and/or additional explosions.

It appears that most of the pipelines in Henderson County were constructed with little or no seismic considerations. Gas pipelines cross under US 60, US 41, and KY 351 at the following locations:

US 60

1. 1.80 miles north of junction of KY 266 and US 60,
2. 0.30 and 0.35 mile south of Canoe Creek bridge.

US 41

1. 0.50 mile north of the

Henderson County-Webster County line,

2. 0.83 mile north of Elam Ditch bridge.

KY 351

1. 3.0 miles east of junction of KY 1539 (heading northeast) and KY 351.

POWER LINES

High voltage power lines also were cataloged during the route surveys. The heights of the lines above the roadway were estimated visually. Power company officials speculated that a number of breaks along each power line would occur during a major earthquake. In most cases, fallen lines would not be transmitting power because power would be automatically cut off within a few seconds in the event of a break.

Additionally, power line support towers could potentially fall across a priority route.

Power lines cross at the following locations on US 60, US 41 and KY 351.

US 60

1. 1.79 miles north of Race Creek bridge,

2. At the junction of KY 1557 (heading south) and US 60,

3. 0.35 miles north of junction KY 266 and US 60,

4. 1.00 mile south of junction of US 41A, KY 425, and KY 136,

5. 0.40 mile north of Canoe Creek bridge.

US 41

1. 0.60 mile north of the Henderson County-Webster County line.

KY 351

1. 2.50 miles east of junction of KY 1539 (heading northeast) and KY 351.

MINES

There are several types of mining-related activities in Henderson County that could affect priority routes during a major earthquake. A large earthquake could collapse pillars in underground mines and cause rapid subsidence at the surface. Other potential hazards exist. Strip mines might have large spoil banks and possible impoundments. Abandoned or current operating mines are located at the following locations:

US 41

1. 2.08 miles north of the Dredge Ditch bridge,

2. 0.29 mile south of the bridge over the Branch of Canoe Creek.

KY 351

1. 1.37 miles east of junction of KY 1539 (heading northeast) and KY 351,

2. 0.38 mile east of junction of KY 1078 (heading southwest) and KY 351,

3. 0.37 mile east of junction of KY 1078 (heading northeast) and KY 351,

4. 0.64, 2.06, 2.09 and 2.99 miles east of the Lick Creek bridge.

KY 416

1. 1.23 and 0.76 miles west of junction of KY 416 and KY 51.

Audubon Parkway

1. 0.89 mile west of the Green River Bridge.

CRUDE OIL STORAGE TANKS

Crude oil is a natural resource in Henderson County. There are several locations along US 41, KY 351, and KY 416 where wells and storage tanks are within 200 feet of the road. A major earthquake could rupture or overturn the tanks, possibly causing explosions and/or fires near the priority route. Crude oil storage tanks were logged at the following locations:

US 41

1. 0.60 mile north of junction of KY 416 (heading northeast) and US 41,

2. 0.60 mile south of the bridge over the East Fork of Cane Creek.

KY 416

1. 0.70 mile west of junction of KY 51 and KY 416.

KY 351

1. 0.50, 0.60, and 1.20 miles west of junction of KY 1078 (heading southwest) and KY 351.

WATER TOWER

A water tower is approximately 40 feet from US 60 at milepost 2.80. It is possible that the tower could fail during a major earthquake and temporarily block the priority route.

WATER IMPOUNDMENTS

Large ponds which have large earthen dams that lie above the road surface could possibly collapse during an earthquake and wash out a section of a priority route. Ponds which lie below the road surface and are adjacent to the toe of the fill slope could cause failures in the fill during an earthquake due to the high moisture content. Three large ponds are located on US 60, 2.00 miles north of junction of KY 266 (heading east-west) and US 60.

RADIO/TV TOWERS

A 300-foot radio tower is approximately 50-feet from KY 351, 0.30 mile east of junction of KY 1539 (heading northeast) and KY 351. It is possible that the tower could fail during a major earthquake and temporarily block the priority route.

TREES

The behavior of trees during an earthquake depends upon many factors including their condition, type, height, and size. Local soil conditions, geometry of the ground surface, and characteristics of the earthquake can also be important. Violent ground motions accompanied by surface rupture and perhaps permanent displacement of the soil surface produce sudden surface

accelerations of the ground which can snap and uproot large trees (3).

Trees are so numerous that, if many of them fell, the priority routes in Henderson County could effectively be blocked for several hours or days before emergency crews could clear the debris. Groups of large trees are located near the road at the following sites:

US 60

1. 1.89 miles north of Race Creek bridge,

2. 0.70, 2.25, and 3.65 miles south of junction of US 41A, KY 425, and KY 136.

KY 416

1. 0.62 and 0.72 mile east of the bridge over Audubon Parkway,

2. 0.10 mile west of junction of KY 51 and KY 416.

KY 351

1. 1.90 miles east of junction KY 1539 (heading northeast) and KY 351,

2. 0.10 and 0.70 mile east of junction of KY 1078 (heading northeast) and KY 351,

3. 4.21 miles east of the Lick Creek bridge.

ALLUVIUM

Soil maps for Henderson County indicate that there are large amounts of alluvium present throughout the county. Alluvium is a loose, fine-grain soil which is deposited by flowing water such as creeks and rivers. Due to the nature of the alluvium, ground motions at the surface of the soil can be many times greater than those within the underlying bedrock and temporary liquefaction can occur (Figure 2). An alluvium map for Henderson County is shown in Figure 3.

CONCLUSIONS

In 1984, ESTS developed a fivefold plan of action for formulating and implementing a seismic mitigation policy for the western Kentucky seismic zone. To date, the Kentucky Transportation Center has established priority routes for all 26 counties in the western Kentucky seismic zone and developed seismic risk maps of all natural and man-made features that are susceptible to earthquake damage that could jeopardize the priority routes.

Current work is being conducted to analyze these features and make recommendations for hardening them against earthquake damage.

Future work involves training key personnel in the Transportation Cabinet in hazard mitigation and seismic safety; which includes bridge inspectors, district engineers, construction inspectors, designers, and maintenance personnel.

Following the education of key personnel, the mitigation plan proposed by the Kentucky Transportation Center will be reviewed by the Kentucky Transportation Cabinet and a program will be established for implementation. The final step involves the use of relevant seismic codes for all new construction, repair, and maintenance.

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2. Green, N. B., "Earthquake Resistant Building Design and Construction," Third Edition, Elsevier, 1987, Page No. 179-180.

3. Keller, Edward A., "Environmental Geology," Charles E. Merrill Publishing Company, A Bell and Howell Company, 1979, Page No. 157.

Additional Information

The Commonwealth of Kentucky has prepared a State Emergency Operations Procedures (State EOP) manual that is produced by the Division of Disaster and Emergency Services (DES), Department of Military Affairs, Frankfort, 40601. Annexes H. on Transportation and DD on Earthquakes give additional information on disaster preparedness and response.

A copy of the State EOP and information on local hazard mitigation activities and response preparedness are available from the AREA 3 Office of DES which is located in Owensboro. The phone numbers at this office are (502) 564-8603 and (502) 683-6254.

Additional information about the study discussed in this report should be directed to David L. Allen, Project Director, at the Kentucky Transportation Center, (606) 257-4513. Requests to be placed on the mailing list for updated information should be submitted on your company or agency letterhead to the Kentucky Transportation Center at the University of Kentucky, Lexington Kentucky 40506-0043.

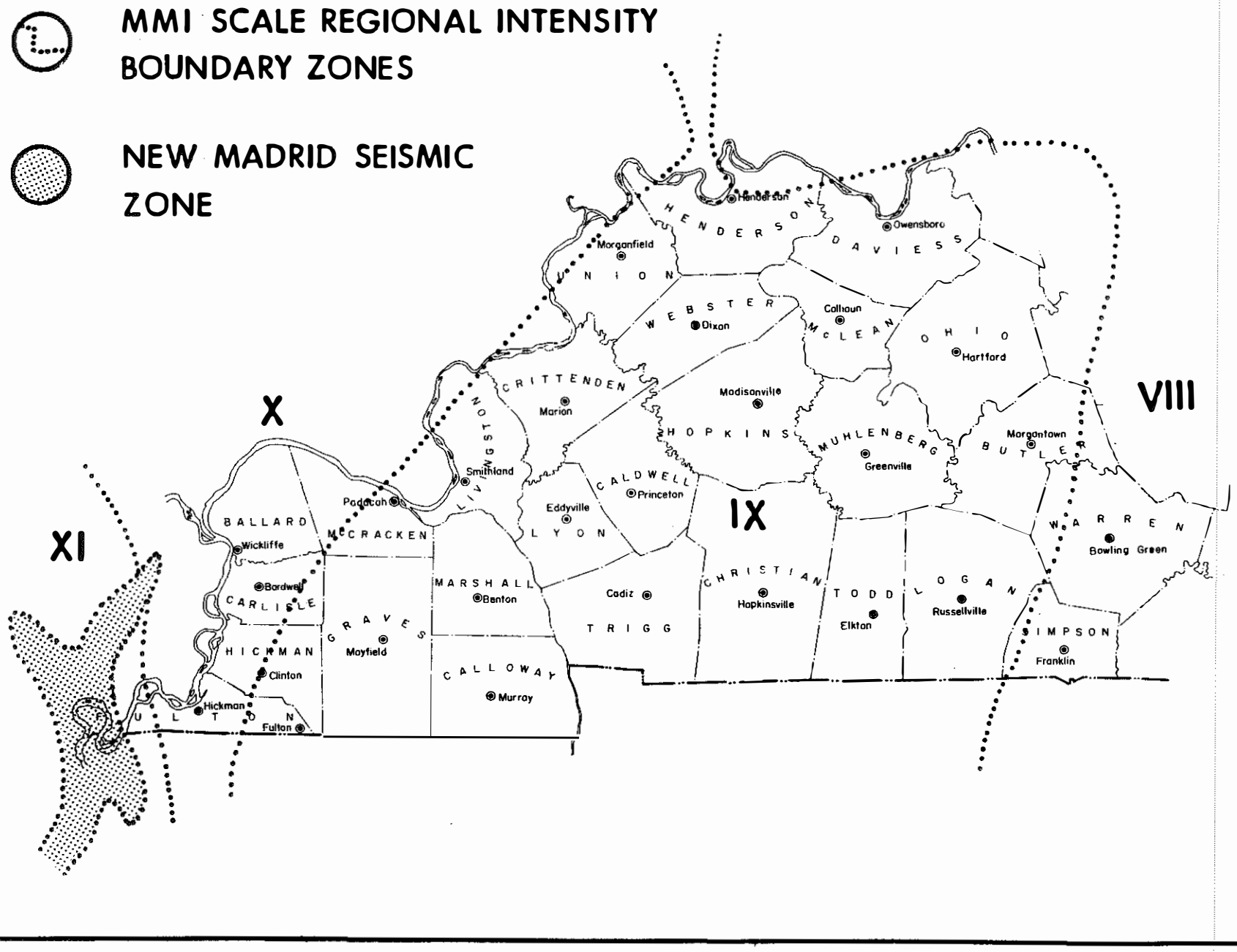


Figure 1: The twenty-six counties included in this study area.

Table 1: MODIFIED MERCALLI INTENSITY SCALE

Modified Mercalli Intensity Scale, 1956 Version

The following comments by Dr. Richter precede the published statement of the intensity scale:

...Each effect is named at the level of intensity at which it first appears frequently and characteristically. Each effect may be found less strongly, or in fewer instances, at the next lower grade of intensity; more strongly or more often at the next higher grade. A few effects are named at two successive levels to mdicate a more gradual increase.

Masonry A, B, C, D. To avoid ambiguity of language, the quality of masonry, brick or otherwise, is specified by the following lettering.

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar, reinforced by not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weakness like failing to tie corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

The following list represents the twelve grades of the scale.

I. Not felt. Marginal and long-period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favorable placed.

III. Felt indoors, Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.

V. Felt outdoors; direction estimated. Sleepers awakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken, Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken.

VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices. Same cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundation if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. Frame structures, if not bolted, shifted off foundations. Frames cracked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand crater.

X. Most masonry and frame structures destroyed with their foundations. Some will-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large land slides. Water thrown on banks of canals, river, lakes, etc. Sand and mud shifted horizontally on beaches and flat lands. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines completely out of service.

XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown in the air.

AMPLIFICATION OF SHAKING
AND
DAMAGE DUE TO SHAKING

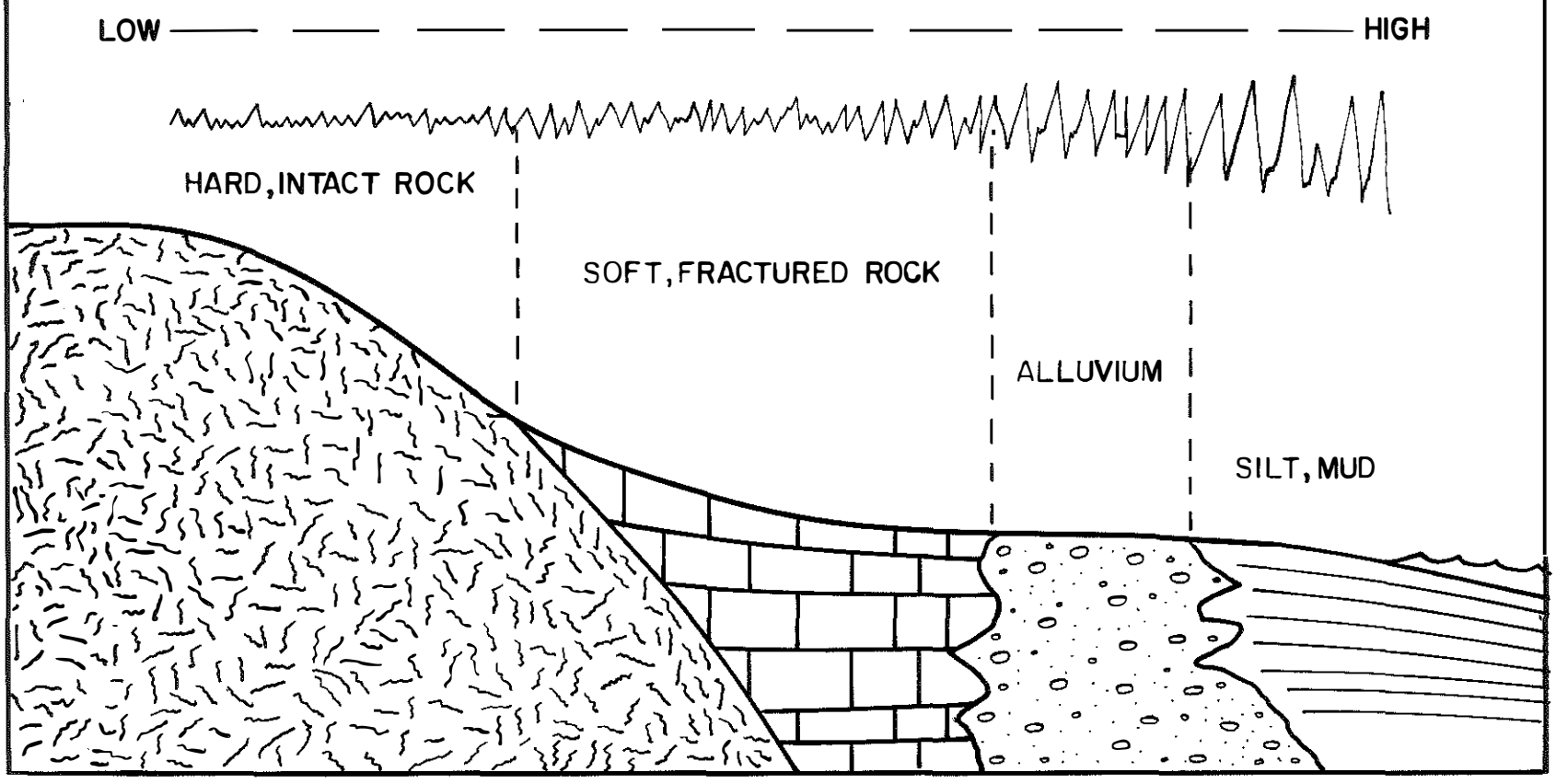


Figure 2 : Amplification of shaking in softer rock & soil during an earthquake.

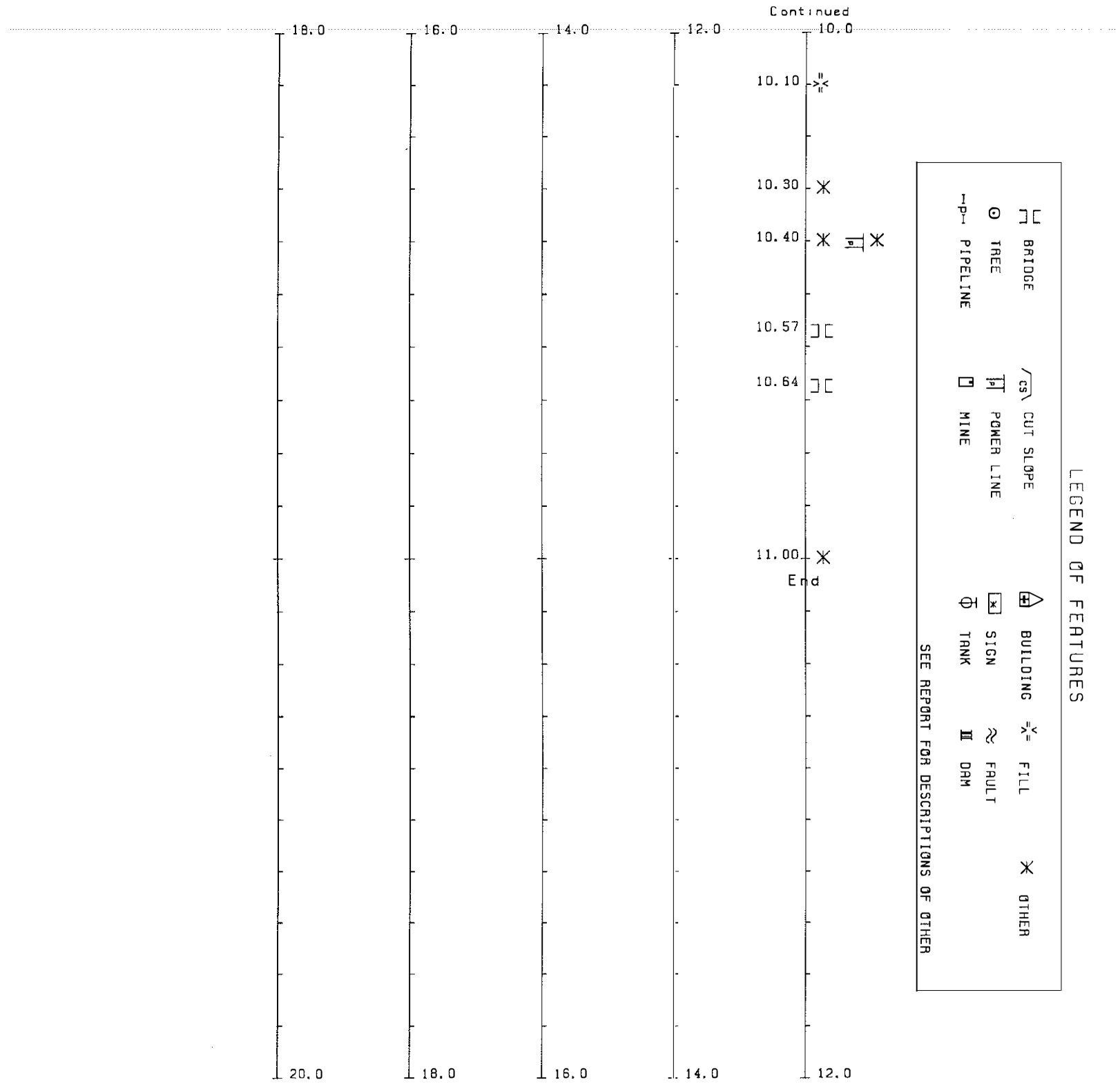
APPENDIX A

STRIP MAP FOR HENDERSON COUNTY

US 60, US 41, KY 351, KY 416, AND AUDUBON PARKWAY

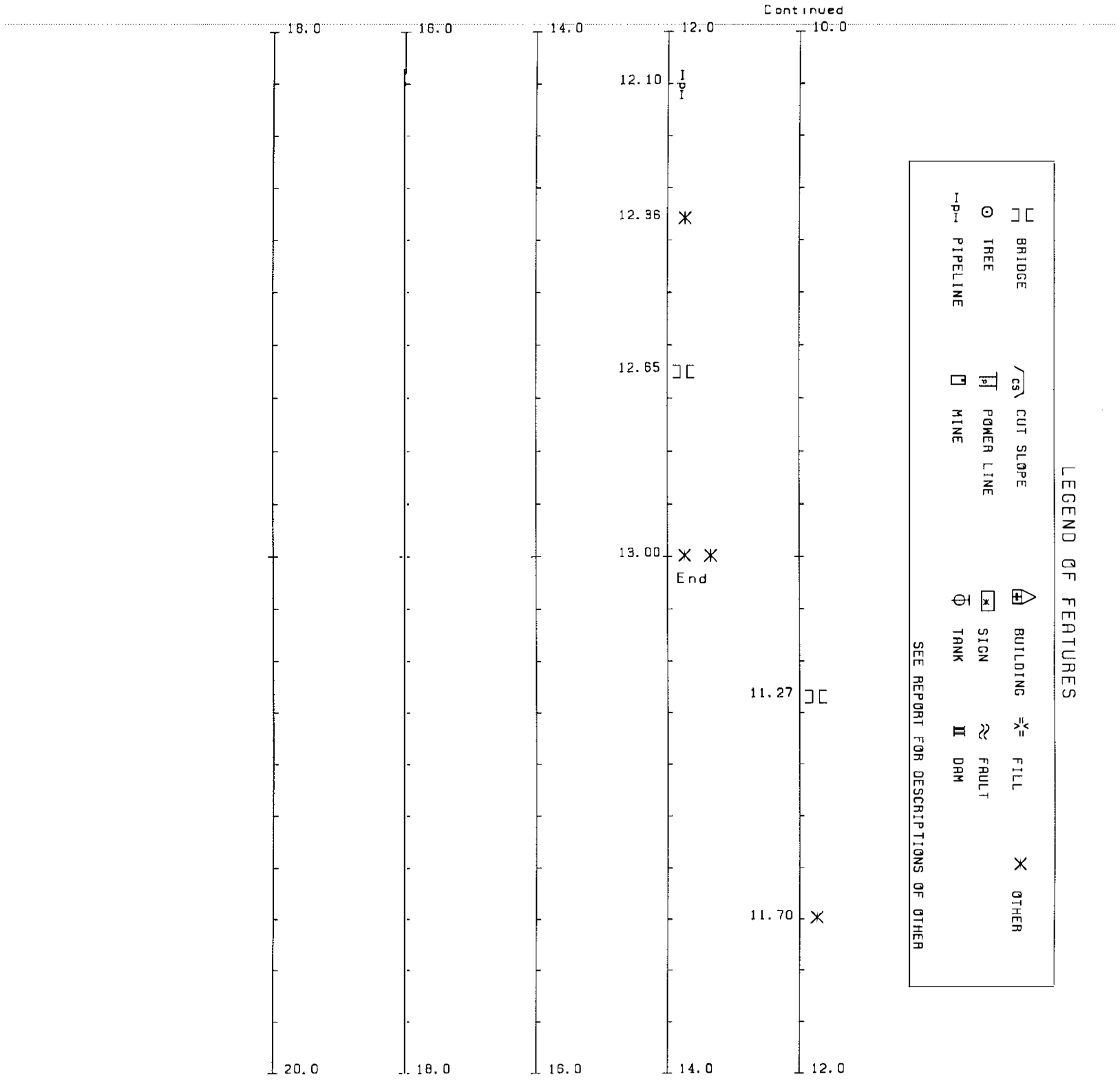
US60 HENDERSON

US60 HENDERSON



US41 HENDERSON

US41 HENDERSON



LEGEND OF FEATURES

BRIDGE
TREE
PIPELINE
CUT SLOPE
POWER LINE
MINE
BUILDING
SIGN
TANK
FILL
FAULT
DAM
OTHER

SEE REPORT FOR DESCRIPTIONS OF OTHER

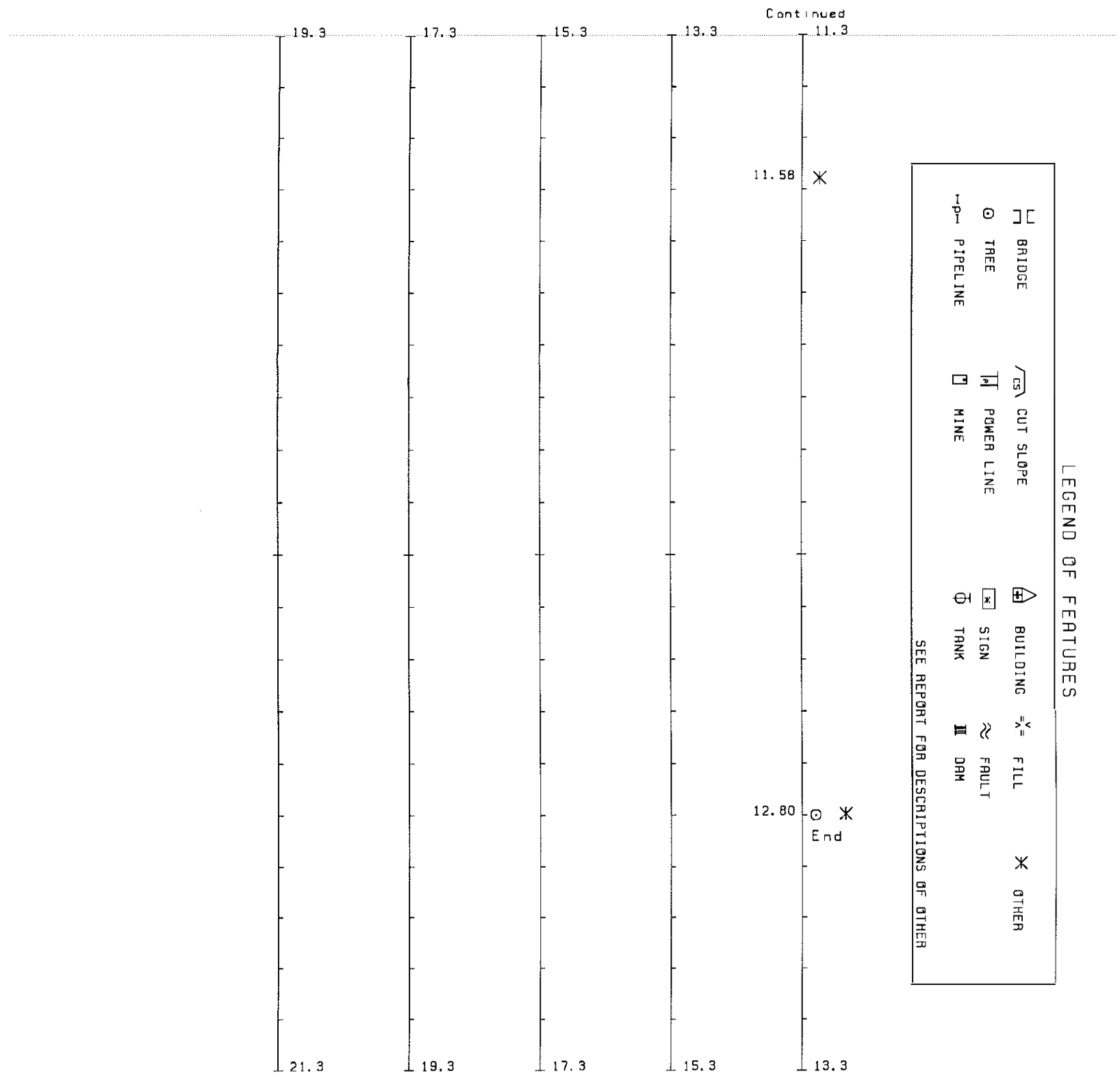
KY351 HENDERSON

LEGEND OF FEATURES

BRIDGE	CUT SLOPE	BUILDING	OTHER
TREE	POWER LINE	SIGN	
PIPELINE	MINE	TANK	
		FILL	
		FAULT	
		DAM	

SEE REPORT FOR DESCRIPTIONS OF OTHER

KY351 HENDERSON



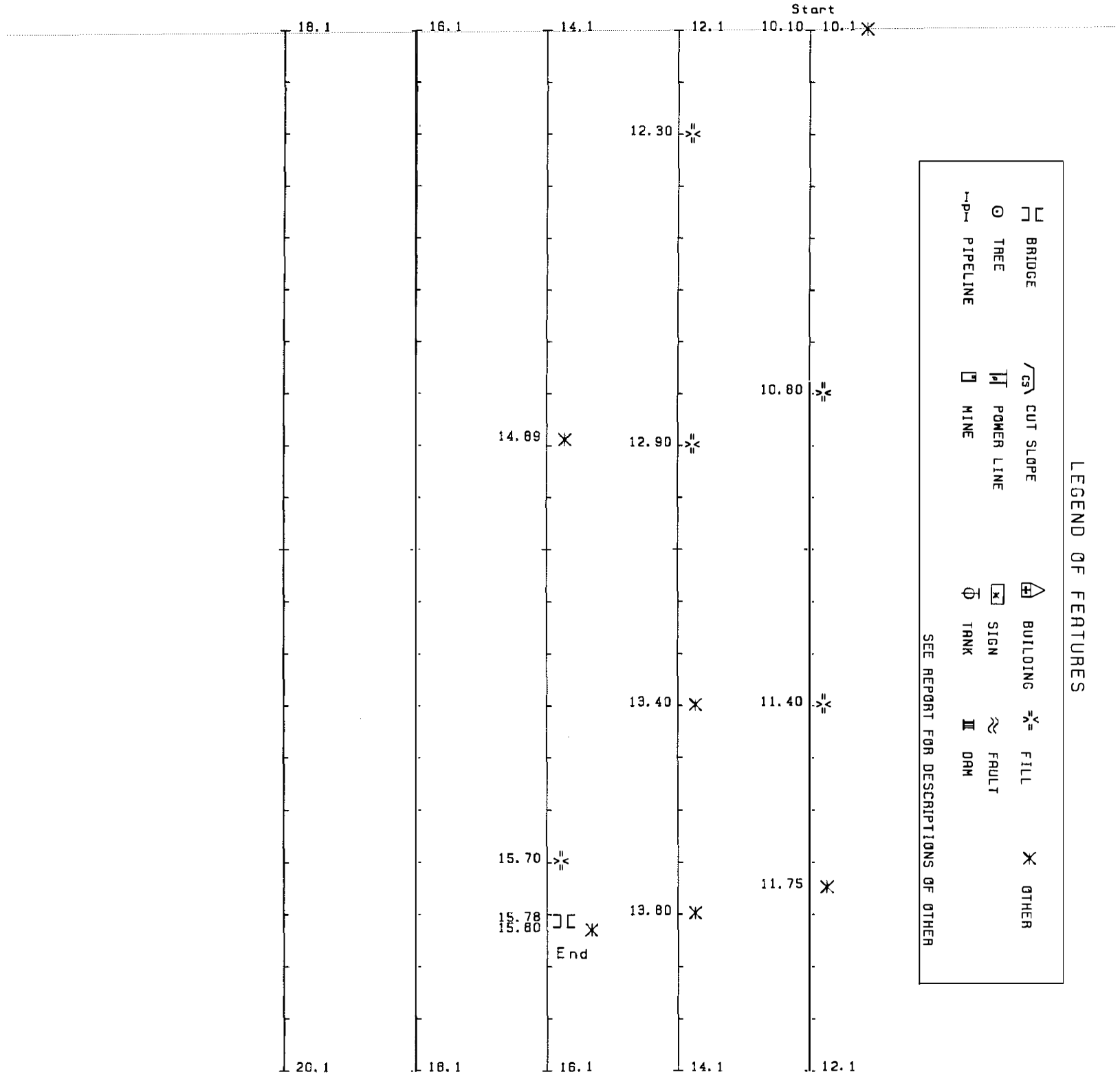
LEGEND OF FEATURES

BRIDGE	CUT SLOPE	BUILDING	
TREE	POWER LINE	SIGN	FILL
PIPELINE	MINE	TANK	FAULT
			DAM
			OTHER

SEE REPORT FOR DESCRIPTIONS OF OTHER

KY416 HENDERSON

A-PKY HENDERSØN



LEGEND OF FEATURES

BRIDGE	CUT SLOPE	BUILDING	OTHER
TREE	POWER LINE	SIGN	
PIPELINE	MINE	TANK	
		FILL	
		FAULT	
		DAM	

SEE REPORT FOR DESCRIPTIONS OF OTHER

APPENDIX B

SEISMICALLY SIGNIFICANT FEATURES

Report by Road and Milepoint
for Henderson County - Kentucky
Audubon Parkway

Milepoint	Feature	Data
10.10	Other	Begin Quake Study on Audubon Parkway Road Surface Type - Rigid
10.80	Fill	Material Type - Soil Height 60 feet Side slope 2:1 Length 400 feet Crest 80 feet Type Fill - Other Road Surface Type - Flexible
11.40	Fill	Material Type - Soil Height 60 feet Side slope 2:1 Length 500 feet Crest 80 feet Type Fill - Other Road Surface Type - Flexible
11.75	Other	Abandoned Gravel Pit Road Surface Type - Flexible
12.30	Fill	Material Type - Soil Height 50 feet Side slope 2:1 Length 200 feet Crest 80 feet Type Fill - Other Road Surface Type - Flexible
12.90	Fill	Material Type - Soil Height 60 feet Side slope 2:1 Length 1,056 feet Crest 80 feet Type Fill - Other Road Surface Type - Flexible
13.40	Other	Same as 13.8 milepoint (Side Stabilized by DGA) Road Surface Type - Flexible
13.80	Other	Road Slide (East Side Embankment Failure) Road Surface Type - Flexible
14.89	Other	Caved Adit (1,000 feet South of road) Road Surface Type - Flexible
15.70	Fill	Material Type - Soil Height 30 feet Side slope 2:1 Length 200 feet Crest 30 feet Type Fill - Side Hill Road Surface Type - Rigid

Report by County and Milepoint
for Henderson County - Kentucky
Audubon Parkway

Milepoint	Feature	Data
15.78	Bridge	Number of Spans 3 Steel Girder I-Beam Bridge Type Unknown End 1 Rocker Pier 1 Rocker Pier 2 Rocker END 2 Rocker Deck Type - Concrete Length 942 feet Width 50 feet Pier Type - Solid SPC Rating - C Surface Type - Flexible Expansion Type - Finger Dam End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown
15.80	Other	Henderson Co - Daviess Co Boundary End of Audubon Parkway in Henderson Co Road Surface Type - Flexible

Report by County and Milepoint
for Henderson County - Kentucky
KY 351

Milepoint	Feature	Data
1.30	Other	Begin KY 351 - Junction US 41 Road Surface Type - Rigid
1.40	Bridge	Number of Spans 3 Underpass Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed End 2 Fixed Deck Type - Concrete Length 150 feet Width 25 feet Pier Type - Open SPC Rating - C Surface Type - Rigid Expansion Type - Other End 1 Substructure - Full End 2 Substructure - Full Foundation Type - Unknown
1.40	Other	City of Henderson Road Surface Type - Rigid
1.40	Other	Repeat Bridge Data For 1.4 milepoint Road Surface Type - Rigid
1.90	Other	Junction KY 1539 Heading Northeast Road Surface Type - Rigid
2.20	Other	Radio Tower 300 feet high, 50 feet from Road Road Surface Type - Rigid
3.27	Other	Abandoned Shaft Road Surface Type - Flexible
3.80	Trees	Number of Trees 100 Height 35 feet Diameter 28 in. Ending Milepoint 3.42 Distance From Road 10 feet Road Surface Type - Flexible
4.40	Power Line	Electrical Power Line 3 Lines Height 35 feet Wood Support Structure Unknown Volts Road Surface Type - Flexible

Report by County and Milepoint
for Henderson County - Kentucky
KY 351

Milepoint	Feature	Data
4.90	Tank	Oil Tank Number of Tanks 4 Capacity Unknown Distance From Road 30 feet Road Surface Type - Flexible
4.90	Pipeline	Pipeline Type - Gas Road Surface Type - Flexible
5.50	Tank	Oil Tank Number of Tanks 15 Capacity Unknown Distance From Road 30 feet Road Surface Type - Flexible
5.60	Tank	Oil Tank Number of Tanks 4 Capacity Unknown Distance From Road 20 feet Road Surface Type - Flexible
5.72	Other	Abandoned Vertical Shaft Road Surface Type - Flexible
6.10	Other	Junction KY 1078 Heading Southwest Road Surface Type - Flexible
6.20	Other	Junction KY 1078 Heading Northeast Road Surface Type - Rigid
6.30	Trees	Number of Trees 20 Height 30 feet Diameter 28 in. Ending Milepoint 6.26 Distance From Road 10 feet Road Surface Type - Flexible
6.57	Other	Abandoned Vertical Shaft Road Surface Type - Flexible
6.90	Trees	Number of Trees 100 Height 30 feet Diameter 24 in. Ending Milepoint 6.80 Distance From Road 10 feet Road Surface Type - Flexible

Report by County and Milepoint
for Henderson County - Kentucky
KY 351

Milepoint	Feature	Data
8.59	Bridge	Number of Spans 4 Over Stream Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed Pier 3 Fixed End 2 Fixed Deck Type - Concrete Length 132 feet Width 22 feet Pier Type - Open SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown
9.23	Other	Abandoned Vertical Shaft Road Surface Type - Flexible
9.23	Other	Dolph Hazelwood Coal Mine - Runs to 10.0 milepoint Road Surface Type - Flexible
10.65	Other	Abandoned Vertical Shaft Road Surface Type - Flexible
10.68	Other	Henderson Co Coal Mine - Runs to 11.58 milepoint Road Surface Type - Flexible
11.58	Other	Abandoned Vertical Shaft Road Surface Type - Flexible
12.80	Trees	Number of Trees 6 Height 40 feet Diameter 30 in. Ending Milepoint 12.79 Distance From Road 10 feet Road Surface Type - Flexible
12.80	Other	End KY 351 Quake Study Road Surface Type - Flexible

Report by County and Milepoint
for Henderson County - Kentucky
KY 416

Milepoint	Feature	Data
16.88	Other	Begin KY 416 Quake Study in Henderson Co Surface Type - Flexible
16.88	Bridge	Number of Spans 2 Steel Girder I-Beam Bridge Type - Over Stream End 1 Rocker Pier 1 Rocker End 2 Rocker Deck Type - Concrete Length 150 feet Width 50 feet Pier Type - Open SPC Rating - C Surface Type - Flexible Expansion Type - Sliding Plate End 1 Substructure - Full End 2 Substructure - Full Foundation Type - Unknown
17.00	Fill	Material Type - Soil Height 50 feet Side slope 2:1 Length 400 feet Crest 30 feet Type Fill - Other Road Surface Type - Flexible
17.50	Trees	Number of Trees 100 Height 30 feet Diameter 24 in. Ending Milepoint 17.60 Distance From Road 15 feet Road Surface Type - Flexible
17.60	Trees	Number of Trees 50 Height 40 feet Diameter 28 in. Ending Milepoint 17.88 Distance From Road 15 feet Road Surface Type - Flexible
17.97	Other	Abandoned Vertical Shaft Road Surface Type - Flexible
18.44	Other	Abandoned Vertical Shaft Road Surface Type - Flexible
18.50	Tank	Oil Tank Number of Tanks 2 Capacity Unknown Distance From Road 30 feet Road Surface Type - Flexible

Report by County and Milepoint
for Henderson County - Kentucky
KY 416

Milepoint	Feature	Data
19.10	Trees	Number of Trees 10 Height 40 feet Diameter 18 in. Ending Milepoint 19.12 Distance From Road 5 feet Road Surface Type - Flexible
19.20	Other	End of KY 416 - Junction KY 351 Road Surface Type - Flexible

Report by Road and Milepoint
for Henderson County - Kentucky

US 41

Milepoint	Feature	Data
0.00	Other	Henderson Co - Webster Co Boundary Road Surface Type - Flexible
0.40	Other	Junction KY 2097 Heading South Road Surface Type - Flexible
0.50	Pipeline	Pipeline Type - Gas Road Surface Type - Flexible
0.60	Power Line	Electrical Power Line 3 Lines Height 25 feet Wood Support Structure Unknown Volts Road Surface Type - Flexible
0.65	Bridge	Number of Spans 3 Over Stream Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed End 2 Fixed Deck Type - Concrete Length 99 feet Width 27 feet Pier Type - Open SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown
3.20	Other	Junction KY 416 Heading Northeast Road Surface Type - Flexible
3.80	Tank	Oil Tank Number of Tanks 4 Capacity Unknown Distance From Road 30 feet Road Surface Type - Flexible
4.90	Other	Junction KY 283 Heading Southwest Road Surface Type - Flexible
5.60	Tank	Oil Tank Number of Tanks 2 Capacity Unknown Distance From Road 30 feet Road Surface Type - Flexible

Report by County and Milepoint
for Henderson County - Kentucky
US 41

Milepoint	Feature	Data
6.20	Bridge	Number of Spans 3 Over Stream Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed End 2 Fixed Deck Type - Concrete Length 99 feet Width 26 feet Pier Type - Open SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown
6.32	Bridge	Number of Spans 3 Over Stream Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed End 2 Fixed Deck Type - Concrete Length 99 feet Width 26 feet Pier Type - Open SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown
8.40	Other	KY 136 Leaves US 41 Heading Southeast Road Surface Type - Flexible
8.63	Other	Abandoned Shaft Road Surface Type - Flexible
11.27	Bridge	Number of Spans 3 Over Stream Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed End 2 Fixed Deck Type - Concrete Length 104 feet Width 26 feet Pier Type - Open SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown

Report by County and Milepoint
for Henderson County - Kentucky
US 41

Milepoint	Feature	Data
11.70	Other	US 41 Joins KY 136 Heading Northwest Road Surface Type - Flexible
12.10	Pipeline	Pipeline Type - Gas Road Surface Type - Flexible
12.36	Other	Abandoned Shaft Road Surface Type - Flexible
12.65	Bridge	Number of Spans 3 Over Stream Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed End 2 Fixed Deck Type - Concrete Length 84 feet Width 26 feet Pier Type - Open SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown
13.00	Other	End US 41 Outside of Henderson Road Surface Type - Flexible
13.00	Other	Junction KY 812 Heading Southeast Road Surface Type - Flexible

Report by County and Milepoint
for Henderson County - Kentucky
US 60

Milepoint	Feature	Data
0.00	Other	Henderson Co - Union Co Boundary Road Surface Type - Flexible
0.01	Bridge	Number of Spans 13 Type Unknown Concrete T-Beam Bridge Bearing Type Unknown Deck Type - Concrete Length 449 feet Width 30 feet Pier Type - Solid SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown
0.01	Bridge	Number of Spans 1 Over Stream Concrete I-Beam End 1 Fixed End 2 Fixed Deck Type - Concrete Length 53 feet Width 25 feet Pier Type - Open SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Full End 2 Substructure - Full Foundation Type - Unknown
1.80	Power Line	Electrical Power Line 3 Lines Height 30 feet Wood Support Structure Unknown Volts Road Surface Type - Flexible
1.90	Trees	Number of Trees 1 Height 80 feet Diameter 36 in. Ending Milepoint 1.90 Distance From Road 20 feet Road Surface Type - Flexible
2.18	Power Line	Electrical Power Line 3 Lines Height 30 feet Wood Support Structure Unknown Volts Road Surface Type - Flexible
2.18	Other	Junction KY 1557 Heading South Road Surface Type - Flexible

Report by County and Milepoint
for Henderson County - Kentucky
US 60

Milepoint	Feature	Data
2.50	Other	Corydon City Limits Road Surface Type - Flexible
2.80	Tank	Water Tank Number of Tanks 1 Capacity Unknown Distance From Road 40 feet Road Surface Type - Flexible
3.40	Other	Junction KY 266 Heading East & West Road Surface Type - Flexible
3.75	Power Line	Electrical Power Line 3 Lines Height 30 feet Wood Support Structure Unknown Volts Road Surface Type - Flexible
5.10	Trees	Number of Trees 20 Height 80 feet Diameter 20 in. Ending Milepoint 5.20 Distance From Road 15 feet Road Surface Type - Flexible
5.20	Other	Gas Pipeline Road Surface Type - Flexible
5.40	Fill	Material Type - Soil Height 20 feet Side slope 2:1 Length 500 feet Crest 40 feet Type Fill - Other Road Surface Type - Flexible
5.40	Other	3 Large Ponds, 150 feet from Road Road Surface Type - Flexible
6.50	Trees	Number of Trees 50 Height 70 feet Diameter 36 in. Ending Milepoint 6.60 Distance From Road 20 feet Road Surface Type - Flexible
7.75	Power Line	Electrical Power Line 3 Lines Height 30 feet Wood Support Structure Unknown Volts Road Surface Type - Flexible

Milepoint	Feature	Data
8.05	Trees	Number of Trees 50 Height 40 feet Diameter 15 in. Ending Milepoint 8.20 Distance From Road 15 feet Road Surface Type - Flexible
8.30	Fill	Material Type - Soil Height 30 feet Side slope 2:1 Length 300 feet Crest 30 feet Type Fill - Other Road Surface Type - Flexible
8.75	Other	Junction US 41A, KY 425, & KY 136 Heading North Road Surface Type - Flexible
9.50	Other	Railroad Crossing Road Surface Type - Flexible
9.65	Other	Gas Pipeline Road Surface Type - Flexible
9.70	Other	Gas Pipeline Road Surface Type - Flexible
9.90	Fill	Material Type - Soil Height 20 feet Side slope 2:1 Length 60 feet Crest 30 feet Type Fill - Other Road Surface Type - Flexible
10.00	Bridge	Number of Spans 3 Over Stream Concrete I-Beam End 1 Neoprene Pier 1 Neoprene Pier 2 Neoprene END 2 Neoprene Deck Type - Concrete Length 222 feet Width 36 feet Pier Type - Solid SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown

Report by County and Milepoint
for Henderson County - Kentucky
US 60

Milepoint	Feature	Data
10.10	Fill	Material Type - Soil Height 20 feet Side slope 2:1 Length 60 feet Crest 30 feet Type Fill - Other Road Surface Type - Flexible
10.30	Other	Steel Tower 100 feet high, 50 feet from Road Road Surface Type - Flexible
10.40	Other	Junction US 41A Headed South Road Surface Type - Flexible
10.40	Power Line	Electrical Power Line 3 Lines Height 40 feet Wood Support Structure Unknown Volts Road Surface Type - Flexible
10.40	Other	Power Lines Parallel to Road (10.4 - 11) milepoint Road Surface Type - Flexible
10.57	Bridge	Number of Spans 3 Type Unknown Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed End 2 Fixed Deck Type - Concrete Length 234 feet Width 54 feet Pier Type - Solid SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Full End 2 Substructure - Full Foundation Type - Unknown
10.64	Bridge	Number of Spans 3 Overpass Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed End 2 Fixed Deck Type - Concrete Length 159 feet Width 30 feet Pier Type - Solid SPC Rating - C Surface Type - Flexible Expansion Type - Other End 1 Substructure - Full End 2 Substructure - Full Foundation Type - Unknown

Report by County and Milepoint
for Henderson County - Kentucky

US 60

Milepoint	Feature	Data
11.00	Other	End US 60 in Henderson Co Road Surface Type - Flexible

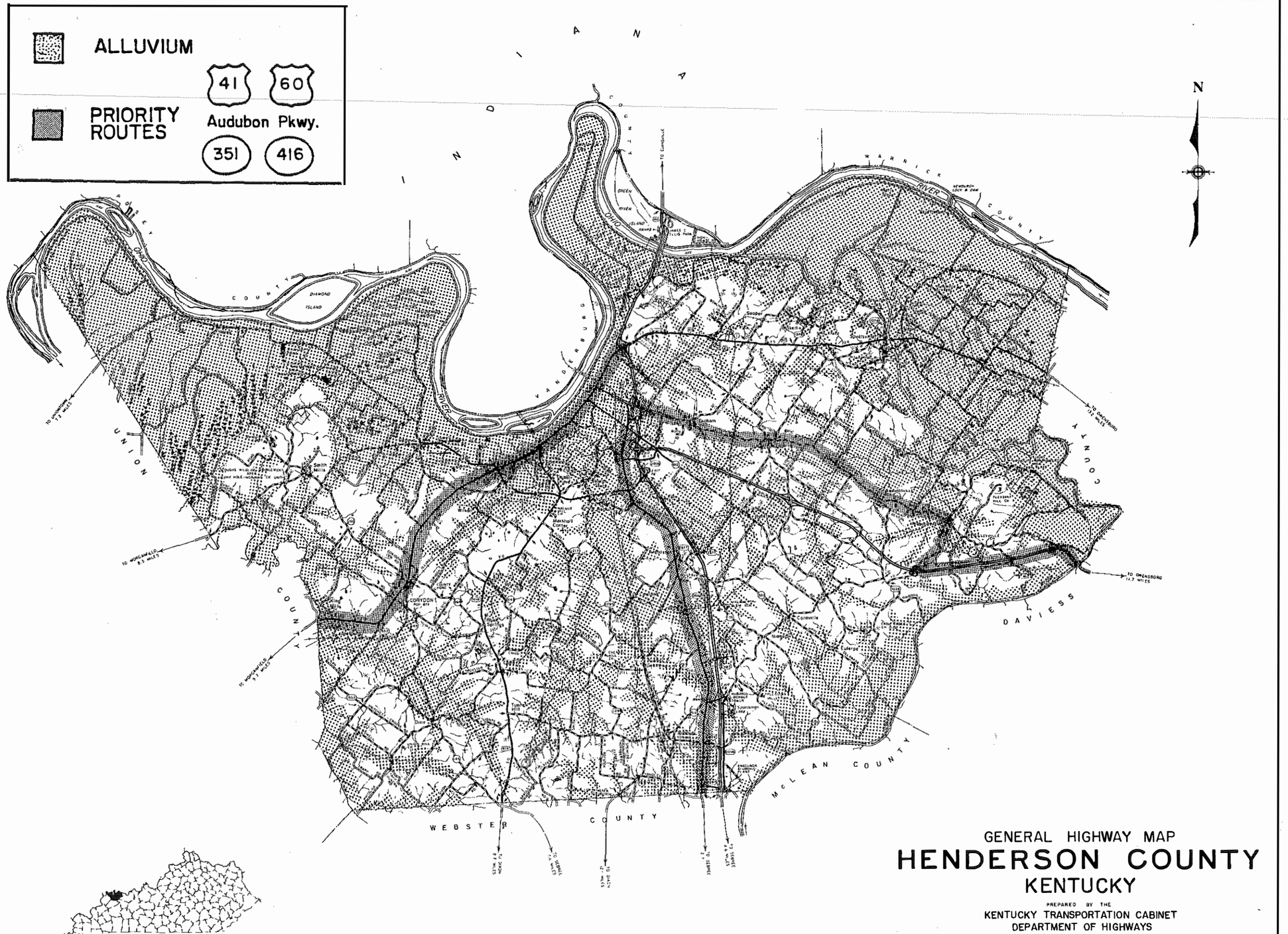


Figure 3. Alluvium map for Henderson County.